United States Army

Group 31 and Group 34 Li-ion Battery Specification

US Army TARDEC Energy Storage Team
2/8/2011

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
08 FEB 2011		

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
BATTERY SPECIFICATION FOR MATV, GROUP 31 AND GROUP 34 LI-ION BATTERY	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
Laurence Toomey	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)	8. PERFORMING ORGANIZATION REPORT NUMBER
U.S. Army TARDEC ,6501 E.11 Mile Rd,Warren,MI,48397-5000	**#21530**
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

The following are requirements for the Li ion rechargeable battery conforming to the Group 31 and Group 34 form factor. These are based on DOD wide Li ion rechargeable draft specification that is currently under development by the DOD Power Sources Battery Technical Working Group. Requirements for the Li ion batteries are broken down into design & construction, performance, environmental, and safety. The battery technical requirements are listed in Table 1. The contractor must provide Material Safety Data Sheet (MSDS) sheets, specific electrochemistry, technical data sheets, cycling data, and independent test data from a second party for the cell identified in the proposal or a similar cell size and electrochemistry being proposed.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**		**14**	

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1 System Performance Requirements

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	Group 31	**Group 34**
Cold Crank Current (30 sec pulse) @ -18°C / -40°C	1000A / 400A	1000A / 400A
Nominal Voltage (V)	12V	12V
Capacity (Ahr) @ 1C, 25°C	150Ahr	100Ahr
Weight	< 25kg	< 16kg
Physical Dimensions, Terminals & Handles	BCI Battery Replacement Book	BCI Battery Replacement Book
Operating Temperature Range	-46°C to 71°C	-46°C to 71°C
Cycle Life (min) 100% DOD 1C / 1C @ 35°C	1000	1000
Shelf Life (months)	30	30

Table 1: Battery Technical Requirements

Reference to Group 31 & Group 34 form factors: http://www.batterycouncil.org/

1.1 Design and Construction Requirements

1.1.1 Battle Override Mode:

All batteries shall have a battle override mode activated by the user allowing for extended operation which could otherwise damage the battery. All critical safety parameters shall not be violated during battle override mode. (Note: It is recognized that operation in this mode can damage the battery.)

1.1.2 Metals/Dissimilar Metals:

All cell or battery metals which do not enter into the basic electrochemical reaction of the cell, shall resist, or be treated to resist corrosion. When dissimilar metals which would adversely affect battery performance are used in intimate contact with each other, protection against electrolysis and corrosion shall be provided. (See MIL-STD-889) Vendor certification is required.

1.1.3 Potting/sealing compounds:

Any potting/sealing compounds for insulating, impregnating, potting and sealing compounds used in manufacturing shall be capable of performing their intended purpose under the use conditions

described herein and shall not flow at high temperature, and shall not crack or draw away from the sides of a container at low temperature. Any compound used shall be non-flammable and non-toxic. Vendor certification is required

1.1.4 Insulating compounds:

Insulating compounds for electrical connectors, wires, and tabs, all points inside a battery that have positive and negative polarity in close proximity shall have not less than one layer of insulation between the positive and negative. Material shall not shrink, soften, or crack during any of the tests of this specification. Vendor certification is required.

1.1.5 Elastomeric materials:

All elastomeric materials used in the battery shall show no cracks, blisters or other deterioration, nor cause degradation of battery performance after being tested as specified herein**.** Vendor certification is required.

1.1.6 Intercell connectors:

All intercell connectors shall be robust and flexible allowing for expansion/contraction during thermal temperature extremes without placing stress on the cell terminals and be by surface –to-surface conduction.

1.1.7 Safety-venting devices:

Each cell and battery shall incorporate a safety-venting device or be designed and manufactured so as to preclude a violent rupture. The battery vent shall not allow water or moisture leakage into the battery unit.

1.1.8 Battery case and/or cover:

The battery case and/or cover shall be capable of maintaining the specified dimensions during the life of the battery and shall have a smooth finish free from pitting, blowholes, rough spots, or other deformations. They shall be fabricated of material having sufficient strength to withstand the environmental and electrical tests specified herein and shall not support combustion nor emit toxic vapors when subjected to flame. Vendor certification for non-flammability is required. When plastics are used for the battery case, the material shall be classified in accordance with UL Standard 94, Test for Flammability of Plastic Materials for Parts in Devices and Appliances, except as otherwise noted herein. Acceptable ratings include: HB; V-0; V-1; V-2; 5VA; 5VB; VTM-0; VTM-1; and VTM-2.

1.1.9 Heaters:

Heaters may be incorporated into batteries to meet the cold temperature requirements. Heater will have dormant mode to allow storage for long periods of time without heater activation. All heater components shall be located ***inside*** the battery container. Heater elements, wire assemblies, and electrical switches/circuits shall be explosion proof and shall be electrically insulated and installed in a manner which minimizes potential battery damage due to electrical shorting, sparking, or other electrical hazards. Both primary and secondary (backup) temperature limiting controls shall be incorporated into the battery's heater electrical circuits to prevent overheating and shall be wired in series. It is expected the battery will be capable of starting the vehicle (30 seconds, 400A) within one minute from the initiation of cranking at -32^{o}C with no prior warming of the batteries. From -46^{o}C to -32^{o}C, the heater can be allowed to operate for up to thirty (30) minutes.

1.1.10 State of Charge indicator:

A state of charge indicator (SOCI) must be easily enabled/disabled to reduce parasitic loads. The SOCI shall be a visual display to indicate approximate SOC based on the reported BMS value. The state of charge ranges of the SOCI displayed shall be as follows:

SEGMENTS	STATE OF CHARGE
0	= 0% (Fully Discharged)
1	= 1 to 20%
2	= 21 to 40%
3	= 41 to 60%
4	= 61 to 80%
5	= 81 to 100%

1.1.11 Data Output:

The in vehicle operator shall have the capability to query the batteries system to determine cycle life and other state of health information. The method of doing this is through CAN. The connector for the unit shall be located on the top cover of the battery case and in such a fashion as to avoid moisture or contamination of the connector.

1.1.12 Built in Test:

The battery shall have provisions to perform built-in tests (BIT) to indicate that the battery's electronics are operating properly. BIT shall be performed when commanded by an external means via CAN. The battery state of health and state of charge shall be checked when the BIT is performed.

1.1.13 Terminal posts:

Terminal posts shall be able to maintain seal under all environmental conditions. Terminal post shall be concentric tapered posts of design and location specified in reference documents in Table 1. The positive tapered terminal shall be identified by a "+" or a "POS" and the negative terminal be a "-" or a "NEG". Tapered terminal post shall withstand torque up to 28.25 Newton-meter (Nm).

1.1.14 Battery Case Design/Dimensions/Features:

The batteries shall be designed to be drop in replacements. Battery case dimensions and features are located in reference documents in Table 1. No special mounting or vehicle modifications shall be needed.

1.1.15 Series or Parallel Connections:

The batteries shall be designed to allow multiple series or parallel connection configurations. Batteries must remain balanced in this configuration while being charged by the vehicle to prevent any safety condition from occurring.

1.1.16 On-Vehicle Charging:

The batteries shall be fully compatible with an on-vehicle charging voltage range of 25-30 volts direct current (VDC) where applicable and interface with vehicle power system (per MIL-STD-1275.).

1.1.17 Standard Battery Charger:

The batteries shall be capable of charging to 100% capacity from a standard 12V or 24V lead acid vehicle battery charger in less than 2 hours from 0% state of charge.

1.1.18 Battery Color:

The battery case and cover color shall be white and in accordance with FED-STD-595.

1.1.19 Cell Protective Coverings:

Cells shall have protective coverings and will not be able to short as a result of inadvertent electrical contact. Cell identification markings shall contain manufacturer name and identification number that is capable of tracing manufacturing date, lot code, cell chemistry, etc.

1.1.20 Battery Markings:

Battery shall be marked in accordance with 3.5.1 of MIL-PRF-32143A. The Battery identification marking shall include identification of Chemistry, Battery Voltage and Full Capacity Rating (Ah), NSN (if available), MFG DATE – Lot Code & Serial Number, Contract number, and Manufacturer, manufacturer location at a minimum.

Note. The lot code shown shall indicate the month, year, and lot of manufacture of the battery by means of a six -digit number in which the first two digits shall indicate the number of the month, the middle two digits shall indicate the year and the last two digits indicate the inspection lot number. Months earlier than the tenth month shall be a single digit preceded by "0". A forward slash (“/”) shall separate the first two digits from the middle two and a dash “-“ shall separate the date code from the lot code.

1.1.21 Materials and Manufacturing:

Conformance shall be verified and demonstrated by inspection of contractor records providing objective quality evidence or certification that design, construction, processing, and materials conform to requirements. Applicable records shall include drawings, specifications, design data, receiving inspection records, processing and quality control standards, vendor catalogs and certifications, industry standards, test reports, and rating data.

1.2 Performance Requirements

1.2.1 Cells Matched Capacity:

Cells used to build each battery shall be matched and the capacity of each cell tested shall not vary from the average capacity obtained by more than ± 2.5%.

1.2.2 Dielectric Strength and Insulation Resistance:

The dielectric strength or leakage current shall not be greater than 0.5 milliamperes RMS and the insulation resistance between them shall not be less than 25 megaohms. For dielectric strength, a direct-current potential of not less than 500 volts ± 25 volts for 60 to 65 seconds shall be applied to current carrying parts of the battery and the battery case, the pins of the auxiliary connector and the current carrying parts of the battery and battery case. For insulation resistance, perform in accordance with MIL-STD-202, method 302, test condition B and apply an alternating current potential not less than 500 volts ± 25 volts for 60 to 65 seconds to the following combination of components listed above.

1.2.3 Operating Temperature Range:

The battery functional operating temperature performance requirements shall be -46°C to 71°C. Batteries shall be capable of operating, accepting full charge and full discharge, at these temperatures. Heaters may be used during charging at the colder temperatures.

1.2.4 Performance tests:

1.2.4.1 Deep Cycle Life:

The batteries shall maintain at least 80% capacity rating after >1000 100% depth of discharge cycles at 35°C. Each cycle shall consist of a 1C rate charge and 1C rate discharge.

1.2.4.2 High Temperature Cycle Life Test:

The batteries shall maintain at least 80% capacity rating after 250 100% depth of discharge cycles at 60°C. Each cycle shall consist of a 1C rate charge and 1C rate discharge.

1.2.4.3 Cold Crank Requirements:

The batteries shall have minimum cold cranking amps (CCA) as defined in Requirements Table 1. The batteries shall have desired cold cranking amps (CCA) as defined in Requirements Table 1. See MIL-PRF-32143A section 4.6.1.3low temperature capacity test.

1.2.4.4 Battery Storage and Charge Retention (capacity fade):

The batteries shall have a capacity fade of no more than 10% over a 90 day period at 40^{o}C. The battery shall have a shelf life of at least 30 months. Shelf life is defined as the battery stored at 100% state of charge and not dropping below 20% state of charge at 25 ^{o} C.

1.2.4.5 Calendar Life:

The batteries' calendar life shall be at least 5 years when properly maintained in storage and when not exceeding cycle life.

1.3 Environmental Requirements.

The following tests will be performed unless specified otherwise:

1.3.1 Altitude:

In addition to passing the UN Manual test for Altitude, the cells and batteries shall provide rated power up to 12,000 ft. above sea-level.

1.3.2 Explosive Decompression:

This test shall be conducted IAW Mil Std 810G, Method 500.5, Procedure IV. The battery/cells must meet the capacity and voltage requirements. No weight loss, venting, leakage, disassembly, nor fire is allowed.

1.3.3 Water Immersion:

Batteries shall be capable of withstanding water immersion without sustaining physical or electrical damage and shall show no evidence of leakage of water into cases. Submerge unit at 20.9^{o} angle for not less than 120 minutes in 5% salt solution (ASTM D-1141) at least 36 inches below surface of water. Full charge/discharge capacities before and after the test shall be within 3% of each other.

1.3.4 Attitude:

Each battery shall be designed for operation in any position and shall meet the specified capacity, voltage and exhibit no electrolyte leakage.

1.3.5 Thermal Shock:

Cells and batteries shall pass the UN Manual Thermal test for shipping. Cells and batteries shall also be subjected to thermal shock temperature cycling in the range of +88^{o}C (+190^{o}F) to -54^{o}C (-65^{o}F) and shall not have any defects as a result of varying rates of thermal expansion or contraction of cell and battery components. Perform testing IAW MIL-PRF-32143A, paragraph 4.4.1. Mass loss of test samples shall not be greater than 0.1%. Full charge/discharge capacities before and after the test shall be within 10% of each other.

1.3.6 Mechanical Shock:

Cells and batteries shall be capable of withstanding mechanical shock environments without sustaining physical or electrical damage. In addition to passing the UN Manual transportation test, requirements from MIL STD 810F (Ref: Method 516.5, Procedure I) shall apply. Mass loss of test samples shall not be greater than 0.1%. Full charge/discharge capacities before and after the test shall be within 3% of each other.

1.3.7 Vibration:

Cells and batteries shall be capable of withstanding vibration environments without sustaining physical or electrical damage. In addition to passing the UN Manual Vibration tests, testing during vibration will be required IAW MIL-PRF-32143A, paragraph 4.4.2. Full charge/discharge capacities before and after the test shall be within 3% of each other.

1.3.8 Humidity:

The operating relative humidity shall be from 0 percent to 100 percent including condensation for 10 cycles. Use MIL STD 810F, Method 507.4. Full charge/discharge capacities before and after the test shall be within 3% of each other.

1.3.9 Sand & Dust:

The batteries shall be able to successfully pass the Sand and Dust test per MIL-STD-810F Method 510.4, Procedure I - Blowing Dust (<149um). Also use Procedure III – Settling Dust (<105um) if battery has heat sinks or exterior features that will result in performance deterioration if settling dust is present. Full charge/discharge capacities before and after the test shall be within 3% of each other.

1.3.10 Salt Fog:

The batteries as installed shall meet all functional requirements and show no evidence of mechanical or performance degradation after exposure to salt fog in its operational or storage configuration. (Ref: MIL-STD-810F, Method 509.4). Full charge/discharge capacities before and after the test shall be within 3% of each other.

1.3.11 Fluid Susceptibility:

Conduct the Fluid Susceptibility test in accordance with MIL STD 810, Method 504 using fuels, hydraulic oils, lubricating oils, and solvents/cleaning fluids. The battery must be capable of operating after exposure to this test. Full charge/discharge capacities before and after the test shall be within 3% of each other.

1.3.12 EMI/EMC:

The batteries shall meet or exceed Electro-Magnetic Interference requirements per MIL-STD-461F. Specifically CE 102, CS 101, CS 114, CS 115, CS 116, RE 102, as well as RE 101, RS 101,and RS 103. In addition the batteries once placed in a system must meet the applicable requirements of Mil STD 464B. Full charge/discharge capacities before and after the test shall be within 3% of each other.

1.3.13 Transients, Surges, and Spikes:

Battery electronics must be able to accept but not generate transients, surges, and spikes as defined in Mil STD 1275.

1.4 Safety Requirements.

The battery shall incorporate safety controls and no additional safeties will be required from the vehicle. Safeties must include the ability to withstand any events due to overcharge, overdischarge, short circuit, over temperature, or other potential hazards that could be commonly seen inside a vehicle compartment where starting, lighting and ignition batteries are located. These safeties should self activate when a potential hazard could occur for the technology and should self reset when the hazard is removed.

Battery packs must meet UN Transportation requirements and NAVSEA (S9310-AQ-SAF-010 and provide documentation with certification.

1.4.1 Cell Safety:

During abuse tests, the cells shall target EUCAR 4 or lower.

1.4.1.1 Cell Overcharge:

Cell shall be characterized in accordance with SAE J2464 and corresponding EUCAR ratings reported to the government.

1.4.1.2 Cell Short Circuit:

Cell shall be characterized in accordance with SAE J2464 and corresponding EUCAR ratings reported to the government.

1.4.1.3 Cell Nail Penetration:

Cell shall be characterized in accordance with SAE J2464 and corresponding EUCAR ratings reported to the government. Modify test to penetration rate of 8cm/s.

1.4.1.4 Cell Crush:

Cell shall be characterized in accordance with SAE J2464 and corresponding EUCAR ratings reported to the government.

1.4.1.5 Cell Leakage:

Cells used to build batteries shall not be subject to leakage in storage or use. After testing, cells shall not exhibit leakage indicated by presence of liquid, white or brown deposits; additionally, mass loss of test samples shall be not greater than 0.1%. Perform test by storing cells at 60 ± 5°C (140°F) for not less than 622 hours (approximately 26 days). Remove from high temperature storage and stabilize cells at the room temperature for not less than 1 hour. Weigh each cell to the nearest tenth of a milligram. Visually examine cells.

1.4.2 Battery Safety:

During abuse tests, the battery shall target EUCAR 4 or lower.

1.4.2.1 Protective Circuitry:

The battery shall use protective circuitry to protect it from over discharge and over charge with temperature compensation.

1.4.2.2 Dormant Mode:

The battery management system shall have a dormant mode to allow minimization of parasitic loads and safe storage. During such mode, the terminals shall not have voltage potential.

1.4.2.3 Battery Short Circuit Protection Tests:

Each battery shall be protected against short circuits. When tested there shall not be any damage to the battery and the battery shall be able to meet the full discharge capacity requirement after full charge. The fully charged batteries shall be tested by shorting across all the positive and negative terminals with a total external resistance not greater than 50 milliohms. After one hour, remove the short from across the terminals and stabilize/charge batteries at room temperature for not less than 2 hours. Full charge/discharge capacities before and after the test shall be within 3% of each other.

1.4.2.4 Battery Overcharge/Electrical Leakage:

The following overcharge test shall be conducted. Fully charge the battery and continue charging the unit at C/2 rate for 24 hours allowing the voltage to rise up to 125% of top of charge voltage. Afterwards, allow batteries to stabilize for 2 hours and connect a 1 mega ohm resistor to the case or ground and between the battery current and sensor terminals. Measured voltages shall not exceed 0.5V. After testing there shall not be any damage to the battery. Full charge/discharge capacities before and after the test shall be within 3% of each other.

1.4.2.5 Battery Over-Temperature Protection:

Battery must contain over-temperature protection to protect the battery from exceeding temperatures above maximum safety threshold. If safety threshold is exceeded, then battery shall be rendered inoperative.

1.4.2.6 Battery Impact Test for plastic case:

The battery case (if plastic case is used) shall show no damage after an impact by a 1 kilogram (kg) free-falling solid steel ball dropped at the heights and temperatures listed below. Test per MIL-PRF-32143A, section 4.3.1.3.

1.4.2.7 Battery Crush test:

Battery shall be characterized in accordance with SAE J2464 and corresponding EUCAR ratings reported to the government.

1.4.2.8 Battery Bullet Penetration (Live Fire) test:

Fully charged batteries shall be penetrated by a bullet. The line of fire of the first battery shall be parallel to the longest axis and through the centerline of the battery. The line of fire of the second battery shall be perpendicular to the longest axis and through the centerline of the battery. Three

bullets of a caliber to be specified (762 and 50 caliber have been used in the past) will be fired through each of the two directions.

1.4.2.9 Battery (Transit) Drop Test:

Batteries shall be capable of withstanding drops at extreme temperature conditions without sustaining physical or electrical damage. A fully charged battery shall be dropped from a height of 48 inches onto a hard surface consisting of concrete. Stabilize batteries at +55 ± 2.7Cº (+130ºF) for first test and repeat test at -29 ± 2.7ºC (-20ºF). The smallest side of the battery perpendicular to the plane of the connector face and nearest to the connector (where applicable) shall be parallel to the concrete surface and facing downward upon release. The unit need not be parallel upon impact. Full charge/discharge capacities before and after the test shall be within 3% of each other.

1.4.2.10 BMS Cell Equalization Checkout:

Monitor each cell in the battery module to verify that the BMS is properly controlling and equalizing the voltages across all cells to prevent overcharging. Utilize manufacturers design manual to properly evaluate operation of equalization circuits.

1.5 Battery Condition for Shipment from Manufacturer

1.5.1 State of Charge:

Each battery shall be shipped in accordance with safety requirements per DOT regulations. Due to possible shipping regulations a charge may be required prior to long term storage.

1.5.2 Operating and Charging Instructions:

Each battery shall be furnished with complete instructions for operation and charging of the battery including preferred and alternate charging methods, as well as an MSDS sheet.

1.5.3 Dust caps/covers/shorting protection:

Batteries shall be supplied with a dust cap or cover over the connector/terminal(s). The dust cap or cover shall be snug-fitting and shall be removable by hand at temperatures from -40 to 55°C (-40 to 130ºF). The material used for the dust cap shall be non-toxic, non-flammable and non-conductive and shall withstand temperatures from –40 to 90°C (-40 to 195ºF) without shrinkage or cracking. The dust cap or cover shall not leave any residue on the battery contacts nor have any adverse affect on the connection interface. They shall also act to insulate terminals/leads from accidental shorting. The dust cap or cover should either be black, closely match the color of the battery, or represent the terminal colors (red = positive, & black = negative). Dust cap or cover compliance to these requirements shall be Vendor certified.

1.5.4 Maintenance:

After delivery from the manufacturer, batteries shall not require any maintenance in meeting the provisions of these requirements.

1.5.5 Age Documentation:

The manufacturer shall provide the following documentation with each delivery of cells or batteries:

a. The maximum age of cells or cells assembled into batteries, from the time of their initial manufacture to the time of their final assembly into batteries shall not be greater than 120

days.

b. Batteries or cells shall be submitted for Government testing within 30 days of final assembly.